strongly punctate. Head emarginate in front and consequently very thin anteroposteriorly. Antennæ brown-black, hairy. Legs brown, trochanters, tips of tibiæ and tarsi pale or whitish. Wings hyaline, fringed with long hairs, forewings with a brown band extending across the stigmal region and another at the apical margin."

FIRST ACCOUNT OF A THERMOTROPISM IN *ANOPHELES PUNCTIPENNIS*, WITH BIONOMIC OBSERVATIONS.

By Werner Marchand.
Department of Animal Pathology, Rockefeller Institute for Medical Research, Princeton, N. J.

In the fall of 1915, while taking part in a survey of the breeding-places of Anopheline mosquitoes in the neighborhood of Princeton, in coöperation with the local Mosquito Extermination Commission, the writer made certain observations on the mosquitoes encountered. This account is restricted to a few facts which appear to be new or serve to clear up some doubtful point in the life history of the mosquitoes.[1]

I. *Bionomics of the Larvæ.*

In the Princeton region, only two species of Anopheles have been recorded, these being *A. quadrimaculatus* and *A. punctipennis*. The latter species is by far the more common, but, since King's experiments (1916),[2] it cannot be regarded as entirely harmless. It is doubtful, however, whether this species, which has been found to occur as far north as Boston, Mass. (Th. Smith),[3] is also in the northern states a regular carrier of malaria.

The larvæ of *A. punctipennis* were kept captive in large numbers and lived best in a flat dish which was left uncovered in order to give free access to the air. In a dish about eight inches in diam-

[1] The writer wishes, on this occasion, to express his thanks for the kind helpfulness through which his work was facilitated by Professor E. G. Conklin and Professor Ulric Dahlgren of Princeton University. Dr. Conklin also had the kindness to revise the English of the MS.

[2] King, W. V. Experiments on the development of malaria parasites in three American species of Anopheles. Jour. Exp. Med., Vol. 23, pp. 703–716, 1916.

[3] Theobald Smith. Notes on the Occurrence of Anopheles punctipennis and Anopheles quadrimaculatus in the Boston suburbs. Jour. Bost. Society of Medical Sciences, Vol. V, pp. 321–324, 1901.

eter, filled to a depth of about one and one-half inches with water from a pond, more than two hundred Anopheles larvæ, mostly collected in a half-grown stage, many of them in very young stages, developed into pupæ. The pupæ when formed were taken out with a pipette and transferred to another jar with provisions for the adults to hatch.

In order to rear Anopheles larvæ successfully, it is necessary to feed them, and this fact has not been sufficiently emphasized. It was found that certain unicellular surface algæ, the species of which could not be determined, form a very satisfactory food. These algæ developed freely in one of the glass-covered aquaria in the Vivarium of Princeton University. In this aquarium they covered the whole surface of the water in a continuous green sheet, which was wrinkled and folded in places through the excessive development of the algæ. In order to transfer these to the culture dishes it was sufficient to dip the finger into this stratum and then dip it into the Anopheles-basin; here the algæ, upon reaching the clear surface of the water, would immediately spread out over the whole surface in the form of a thin, opaque, green layer. The Anopheles larvæ would at once start feeding upon these minute algæ, a clear area soon forming around the head and mouthparts of each larva. Before evening, the larvæ had cleared the whole surface of algæ. The procedure was repeated at night in order to provide food for the larvæ to last until the next morning, when again the algæ had been completely devoured. In this way they were fed regularly twice daily. Under ordinary conditions, when Spirogyra or other filamentous algæ are given as food (C. A. Smith),[1] many larvæ usually die, because, as a matter of fact, their natural way of feeding is at the surface. Howard, Dyar, and Knab (1912)[2] suggest that, to provide food the jars in which Anopheles larvæ are grown, should be kept uncovered, "in order that the dust from the air may settle continuously upon the water." Undoubtedly, the Anopheles larvæ may feed on surface bacteria or protozoa, but in absence of green plants, the contamination of the water often causes death. When surface algæ are given, as in the case here recorded, practically no larvæ are lost, because these algæ produce oxygen

[1] Cora A. Smith. The Development of *Anopheles punctipennis* Say. Psyche, Vol. XXI, p. 1.

[2] Howard, Dyar, and Knab. The Mosquitoes of North and Central America and the West Indies. Vol. 1, 1912.

in abundance, and the water does not have to be renewed at all. The quantity of algæ devoured by the larvæ was quite considerable. Lack of attention to this detail may perhaps explain the frequent failures in rearing Anopheles larvæ.[1] On the other hand, the use of surface algæ as food may serve to determine with exactness the quantity of food consumed by a single larva, since the algæ, under carefully chosen conditions, cover the surface quite evenly in a layer of measurable thickness, and therefore the quantity of algæ present on a surface of given dimensions and consumed in a given time may be estimated or calculated, and, divided by the number of larvæ feeding on this surface, would give the quantity consumed by a single larva. However, as the season was advanced, and the larvæ were transforming into pupæ, this experiment was not carried out.

The larvæ showed in a remarkable degree the characteristic instinct spoken of by Zetek,[2] to drop to the bottom when a shadow passed over their heads. When the writer came near them, in the morning, after they had been completely undisturbed for many hours, the phenomenon was particularly striking. The larvæ would drop almost simultaneously and then would remain at the bottom for several minutes.

In this connection, it may be noted that Graham has stated that, in the Sudan, microscopic fresh-water algæ form the principal food of Anopheles, a fact not unimportant for their control, since it may be that the mosquitoes may be kept in check by methods aiming at a destruction of the algæ.[3]

II. *Bionomics of the Adult Stage.*

The resting position of Anopheles has often been used as a characteristic to distinguish the malarial mosquito from other species, the Anopheles holding the body, as a rule, at a certain angle to the surface on which they are resting. This angle is, in *A. punctipennis*, usually about 45°; Nuttall and Shipley's illustration as reproduced

[1] W. M. Graham (A study of Mosquito larvæ, Jour. Ent. Research, Vol. I, 1910) has stated correctly that failure to rear the larvæ is not to be wondered at when it is recognized that mosquito larvæ require a constant supply of special food, consisting usually of living fresh-water algæ. In the absence of algæ the larvæ become cannibalistic and destroy one another.

[2] Zetek, James. Behavior of *Anopheles albimanus* Wiedemann and tarsimaculatus Goeldi. Ann. Ent. Soc. of America, VIII, 1915, p. 221 ff.

[3] Graham, loc. cit.; these algæ were not surface algæ but were suspended in the water; as stated, however, the Anopheles larva is mainly a surface feeder.

by J. B. Smith (Mosquito-control exhibit, N. J. State Museum),[1] in which it is represented to form a right angle with the surface, is an extreme case and not quite typical. It seems, however, that mosquitoes which rest for many hours in the same place, assume a more oblique position than do these which have just alighted. These characteristics apply only to *Anopheles punctipennis*, not to *A. quadrimaculatus*. Hibernating females of the latter species were observed beyond doubt in a resting position in which the body was held about parallel to the resting surface, as illustrated in the accompanying drawing from nature (Fig. 1). Hence, they can be easily mistaken for Culex if only the resting position is taken as a criterion.[2]

Fig. 1. Resting position of hibernating female of *Anopheles quadrimaculatus*. Sketch-drawing from Life.

Concerning the biting position of Anopheles, Nuttall and Shipley's illustration (J. B. Smith, N. J. State Museum exhibit) is not entirely correct (Washburn),[3] and H. P. Johnson[4] is in error in assuming that the mosquito must necessarily bite with proboscis inserted at a right angle. As a matter of fact, *A. punctipennis* will insert the proboscis usually at an oblique angle, the mosquito biting in a position much like the resting position, and the line of the proboscis forming the continuation of the longitudinal axis of the body. This is evidently of advantage for the sucking mechanism.

III. *The Biting Instinct due to a Thermotropic Reaction.*

Observations were also made on the biting instinct, which as it seems, is determined mainly by thermotropism. Patton and Cragg (1913) have reported[5] that Howlett observed that females of

[1] Nuttall and Shipley. The structure and biology of *Anopheles maculipennis*, Jour. of Hygiene, 1901.

[2] Howard (loc. cit. p. 205) has recorded the same fact for *A. quadrimaculatus* hibernating in barns in southern Idaho.

[3] Washburn, F. L. Economic Entomology at the World's Fair. Science N. S., Vol. XX, No. 518, 1904, and "The Biting position of Anopheles." Science, N. S., Vol. XXI, p. 228, 1905.

[4] J. B. Smith. How does Anopheles bite? Science, N. S., Vol. XXI, pp. 71–72, 1905.

[5] Patton and Cragg. Textbook of Medical Entomology. London, Madras and Calcutta, 1913.

Stegomyia scutellaris were attracted by the hot air radiating from a test tube filled with hot water. On the other hand, shed blood and sweat did not attract the ♀ ♀ of this species and *Culex fatigans* any more than water. Howlett's experiments were not known to me at the time when these observations were made, and since they were obtained independently of other observers, and the phenomenon was not known to apply to Anopheles, I may briefly report on them here, especially as data on thermotropism in insects are very scanty. The Anopheles which were kept in lamp chimneys for other purposes, were fed on apple jelly which was spread out on a glass plate. In order to prevent the mosquitoes soiling their legs and wings, the jelly was covered with filter paper. In the intention of providing a food as natural as possible, I heated the apple jelly on the glass plate, assuming that it would then be taken more readily. This was in fact the case. The mosquitoes came quickly to the filter paper and would bite through it as if it were human

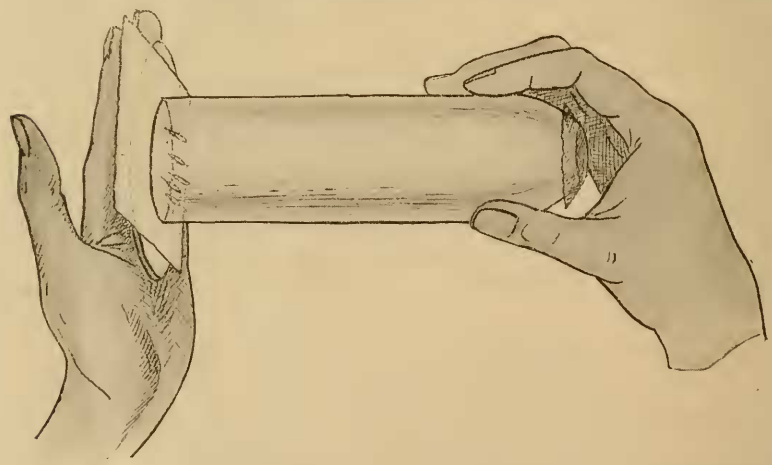

Fig. 2. Arrangement used in demonstrating the thermotropism of mosquitoes.

skin. The question suggested itself whether they were attracted by the odor of the jelly or, possibly, by the heat radiating from it. Being curious whether the mosquitoes would be attracted also by heat alone, I substituted for the glass plate which was covered with jelly, a clean one which was heated to a degree fairly above human body temperature but, of course, not excessive, and covered with

filter paper in the same way as before, in order to provide a foothold for the insects. The mosquitoes were attracted under these conditions in the same way as if food had been present, each one attacking the surface of the filter paper which covered the glass plate, and all bending their proboscis in repeated efforts to pierce the surface. The number of mosquitoes used was about five or six at a time. The arrangement was that given in the diagram (Fig. 2). If several mosquitoes are used in biting experiments, there will usually be some individuals which will show no inclination to bite, but the percentage of individuals not attracted by the heated glass plate, was about the same, and not greater than in the biting experiments. The males showed the same tropism as the females but much less strongly. As soon as the glass plate had cooled off, the mosquitoes became indifferent. However, the experiment could be repeated with the same mosquitoes as also with different sets and always with the same results.

These observations, taken together with those made by Howlett, indicate that this thermotropic reaction is a very important factor to be considered in the analysis of the bloodsucking instinct.

I have, since, tried to confirm these facts by observations on other species of mosquitoes, but so far have used only the hibernating females of *Aëdes sylvestris*. These, however, did not show even a trace of the thermotropic reaction observed in A. punctipennis. On the other hand they also consistently refused to bite, though various food other than blood was readily accepted. Females of Anopheles are known to bite occasionally in winter, and therefore, usually hibernate in stables where blood can be obtained (Grassi and others; see Howard, Dyar and Knab),[1] while Aëdes which hibernates in cellars, seems not to bite at all during the winter even if brought into a heated room. The absence of thermotropism would, therefore, in this case, be only an adaptation to the conditions of hibernation, during which no blood food is taken, and it is perfectly possible, that *Aëdes sylvestris* will be found thermotropic during the "biting season" unless, in this genus, other tropisms are involved.

[1] Loc. cit. p. 206–209.